Mechanical Alloying Program at UMBC

This homepage contains information on the Mechanical Alloying Program at the Physics Department of the University of Maryland Baltimore County.

For a short life story with links to sites of personal and professional significance visit my Personal Homepage.

Did you know that the first documented metallurgical process happens to use grinding in a mortar rather than heat to make a pure metal from its ore?

Principal Investigator

Laszlo Takacs, Associate Professor
M.S. in physics, 1974
Ph.D. in solid state physics, 1978
both from the Lorand Eotvos University, Budapest, Hungary
View a current (June 2001) picture of me at my desk.

Research Associate

Valerii Soika
M.S. in physics, 1993, Donetsk State University, Ukraine
Ph.D. in physics of magnetic materials, 1999, Charles University, Prague

Current and former students

Dan Masters (undergraduate)
Andrew H. Weber (undergraduate)
David V. Wolfe (undergraduate)
Inhee Rhee, M.S. 1994
Mark A. Susol, M.S. 1995

Funding

Current

Combustion Reactions Induced by Ball Milling, NSF DMR-9712141, 1998-2002

Former

Nanocrystalline Materials by Mechanical Alloying and Suitability for Armor Applications, ARL, 1995-1997 (co-investigator)
Several DRIF funds from the UM Graduate School, 1990-1997

Research Topics

Mechanical alloying was originally invented as a method to manufacture oxide dispersion strengthened nickel alloys. It is a high energy ball milling process, where alloying is the result of repeated fracture and cold welding of the component particles. Highly metastable materials such as amorphous alloys and nanostructured materials can be prepared by the process. High energy ball milling can also induce chemical reactions. The research area

of mechanochemistry was developed to study and utilize these processes. As many mechanical alloying processes involve chemical changes, the distinction between mechanical alloying and mechanochemistry is often arbitrary.

Ball milling induces MSR (mechanically-induced self-sustaining reaction) in many highly exotherm powder mixtures. We investigate this phenomenon to gain insight to the mechanism of ball milling. The formation of sulfides, borides, carbides, silicides from the elements and displacement reactions between an oxide, sulfide, or halide and a more reactive metal are investigated. At present, this is the most active area of research within the program.

More detailed description of the specific research areas and a list of the relevant publications, most with abstract can be viewed at the following sites:

Mechanochemistry
Mechanical alloying
Nanocomposites
Metallic glasses
Other publications

Major Equipment

Sample preparation

Three SPEX 8000 Mixer Mills
Fritsch Pulverisette-5 Planetary Mill
Fritsch Pulverisette-0 Vibratory Mill
Stainless steel double glove box (<1 ppm oxygen)
Labconco fiberglass glove box
Fume hood

Sample characterization

Philips X'Pert X-Ray Diffractometer (Theta-Theta, room and high temperature)
Philips PW 1729 X-Ray Generator (with Theta-2*Theta goniometer)
Lake Shore 7307 Vibrating Sample Magnetometer (with furnace and cryostat)
Shimadzu DTA-50

Coollaborations

Peter Balaz
Institute of Geotechnics, SAS
Kosice, Slovakia
View a picture of Peter in the XRD lab when he visited UMBC in 2001.

Ali Bakhshai
Department of Physics
Goucher College, Towson, MD *Marta Pardavi-Horvath*
Institute for Magnetics Research
The George Washington University, Washington, D.C.

Robert C. Reno
Department of Physics
University of Maryland, Baltimore County

Akhtar S. Khan
Department of Mechanical Engineering
University of Maryland, Baltimore County

Santosh K. Mandal
Department of Chemistry
Morgan State University, Baltimore, MD

Lajos K. Varga
Research Institute for Solid State Physics
Budapest, Hungary

Vijayendra K. Garg
Instituto de Fisica
Universidade de Brasilia, Brasilia, Brazil

Erno Kuzmannn
Department of Nuclear Chemistry
Eotvos Lorand University, Budapest, Hungary

Karoly Lazar
Institute of Isotopes and Surface Chemistry
Budapest, Hungary

Dereje Seifu
Department of Physics
Morgan State University, Baltimore, MD

Vladimir V. Boldyrev and Farit K. Urakaev
Institute of Solid State Chemistry
Novosibirsk, Russia

Francisco H. Sanchez
Department of Physics
Universidad Nacional de La Plata, Argentina

Lawrence H. Bennett,
Institute for Magnetics Research
The George Washington University, Washington, D.C.

Robert D. Shull, and the
Magnetic Materials Group
National Institute of Standards and Technology, Gaithersburg, MD

Other related sites of interest

La MŽcanoSynth□se - French Society of
University of Western Australia Research Centre for Advanced Mineral and Materials Processing
Prof. Michael Atzmon at U. Michigan, Ann Arbor
NIST Magnetic Materials Group, Gaithersburg

[ISMANAM 2001](http://) conference home page
Photos at ISMANAM'01

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Mechanical Alloying Laboratory

Lab ratory

People

Research

Publications

Mechanical Alloying Laboratory

Mechanical Alloying is a high-energy ball milling technique used to prepare alloy powders with a precise compositional control and a notable grain size refinement down to the nanometer-scale. The resultant powders develop through the repeated cold-welding and fracture of the elemental (or pre-alloyed) powders particles by the highly energetic compressive impact forces in the ball mill. This technique is also unique in that alloy formation is a solid state process where some of the restrictions of equilibrium phase formation may be overcome.

Since 1996 personal from Metallurgical and Physics Deparments joined efforts to investigate this exciting new field of Materials Science. Currently our M.A. L. is housed in the Physics Department (rooms 8 and 9 in the basement of block B).

Although, sometimes we use hammers - like in the ancient times - the high-tech milling equipment in the laboratory includes:

- Vibratory Fricht Pulverisette 0
- Planetary ball mill Pulverisette 5
- Spex 8000 high energy ball mill

Our group often works in collaboration with others groups from and out of the country, sometimes hosting (-), and sometimes travelling (+). It is like doing Materials Science with a suitcase.

Currently, we are collaborating with groups in Argentina, Brazil and Spain.

Condensed Matter and Materials Physics

Defects in Semiconductor Devices

Understanding the role of deep levels and how to control them is essential in semiconductor device technology because deep states can have strong effect on the electrical performance of devices. Also deep levels associated with lattice defects introduced by particle irradiation are a major cause of device failure in satellites. We study deep levels using a technique called Fourier Transform Deep Level Transient Spectroscopy using a commercial digital system made by BioRad (DL 8060) with optical excitation, a fast pulse interface and a constant capacitance feature.
The group works closely with researchers at the Naval Research Laboratory in Washington, DC.

Group Members
Dr. Geoffrey P. Summers

Mechanical Alloying Group

Mechanical alloying is a [redacted] process that is used toprepare nanostructured materials, amorphous alloys, stable and metastable compounds, etc. As its application does not require high temperature, it is capable of combining components that are incompatible for most other bulk processing methods. High energy ball milling can also be used to induce chemical reactions. Termed mechanochemistry in this case, the method finds applications in a variety of areas: It is the basis of inorganic and organic preparation processes, activation of silicates (cement), the processing of minerals and ceramics, etc. Broader application of ball milling methods require better understanding and control of the process. Our interest is to study exactly what happens inside the milling container, how material properties and milling conditions influence the kinetics of the process and the structure and properties of the resulting products. An interesting situation is when ball milling induces a self-supporting thermal reaction (gasless combustion) in a highly exothermic system. For example, milling titanium and boron powders results in the combustive formation of titanium diboride, a refractory compound often used to enforce light high temperature alloys. Our investigations of the combustive ball milling process gave better understanding of the mechanism of mechanochemical reactions.

We are also interested in utilizing mechanical alloying to prepare materials with interesting properties, especially magnetic properties. Magnetic nanocomposites were prepared, some with the assistance of in situ chemical reactions. Many investigations were performed on the Fe-Zn-O system, with the purpose of preparing nanocomposites of Fe particles in ZnO.

Major equipment
SPEX 8000 and Pulverisette-5 ball mills
X-Ray Diffractometer (Philips X'Pert)
Vibrating Sample Magnetometer (Lake Shore 7307)

High Temperature DTA (Shimadzu DTA-50)
Double Width Glove Box

Group Members
Laszlo Takacs, Associate Professor
Valerii Soika, Research Associate
Andrew H. Weber, Undergraduate Assistant

Microscopy and Materials Characterization Group

Current research addresses the characterization of the morphology, composition, and magnetic and crystallographic structure of mechanically alloyed powders (e.g., Ta-S alloys), thin films (e.g. NiO), and highly deformed metals (steel sheet). Techniques used include scanning electron microcopy (SEM), energy dispersive x-ray spectroscopy, electron backscattered diffraction (EBSD), and atomic force microscopy (STM/AFM).

Supporting techniques used on occasion are Mossbauer spectroscopy and positron annihilation.

Major equipment
JEOL JSM-5600 SEM with Oxford Isis (x-ray) and Opal (EBSD) attachments
Thermomicroscopes STM/AFM
Mossbauer spectrometers and a delayed coincidence gamma ray spectrometer.
Sample preparation facilities
high temperature vacuum annealing furnace
sample polishing and sputtering apparatus
optical metallography.

Group Members
Dr. Robert C. Reno, Associate Professor
Christa Shockey, Graduate Research Assistant
Patrick Hughes, Undergraduate Research Assistant

Surfaces & Interfaces Group

Our research is concerned with the effects of surfaces and interfaces on the magnetic properties of materials. We have studied surface effects on magnetic phase transitions in the antiferromagnet UO2 using resonant magnetic x-ray scattering. We found that the moments near the surface disordered at a lower temperature than the moments in the bulk. We are performing similar studies using low-energy electron diffraction to study the magnetic structure at the (001) surface of the antiferromagnet NiO. The surface magnetic structure of NiO is studied as a function of both temperature and film thickness.

Our group is also interested in magnetic multilayers and the phenomena of giant magnetoresistance. We have grown magnetic tri-layers at NIST in collaboration with the Quantum Metrology Group. Experiments are underway to study the induced moments in the non-magnetic spacer layers of these samples as a function of distance from the

ferromagnetic-nonmagnetic interface.

Major equipment
ultra-high vacuum (UHV) surface chamber with high-resolution
low-energy electron diffraction (HR-LEED)
double-pass cylindrical-mirror analyzer, and e-beam evaporator
four-circle x-ray diffractometer for sample characterization.

In the near future we will have a second UHV chamber with a photoemission-electron microscope for imaging of magnetic domains in thin films.

Our group is a member of the X22C PRT at the *National Synchrotron Light Source at Brookhaven National Laboratory*. Work has also been performed at the *ESRF (European Synchrotron Radiation Facility)* using beam line ID20.

Group Members
Dr. Gavin M. Watson - Assistant Professor
Jason Cheng- Research Assistant
Rundong Wan- Research Assistant
Recent Graduates
Matthew Brown- Master's (Jan '00). Currently at NIST
Brian Hinz- Master's (Jan '00). Currently at National Semiconductor

Theoretical Surface Physics

Our research is based on the theory of electron scattering and transport at interfaces and the exploitation of such processes for surface modification and the manipulation of chemical dynamics at surfaces. The research is a collaborative effort involving both theoretical and experimental researchers at UMBC and elsewhere and the group offers an ideal environment for those interested in theoretical physics that has a direct connection to experimental research..

Currently, we have active research projects in the two areas described below:

Transient Electronic States At Surfaces and Surface Dynamics

A fundamental aspect of the microscopic description of surface dynamical processes is the understanding of transient electronic states of adsorbed atoms and molecules and how these excited states couple to inelastic decay channels such as vibrational excitation, dissociative attachment and desorption. At the most fundamental level, such transient electronic states are the most elementary steps in many surface chemical reactions.

Currently, we are developing new theoretical methods which will allow the computation of the lifetime of excited electronic states in adsorbed molecules, a quantity that can be regarded as a controlling parameter in many surface dynamical processes. We are trying to answer the question: Is it possible to control the lifetime of excited states by altering the scattering environment of the atom or molecule?. We are exploring an elegant analogy to be found in the classic quantum electrodynamical problem

of the radiative decay of excited atomic states in micro-cavities. Our ultimate goal is to develop our fundamental understanding of the decay of resonant states to level where it becomes possible to design nanoscale structures at surfaces which would allow the control of the temporal evolution of excited states in adsorbates. From a technological viewpoint this goal has applications in the control of surface chemical reactions, molecular electronics and sensor technology.

Surface Electromigration

A fundamental question faced in development of new processes for surface modification is: how is it possible to influence, externally, the morphology of the surface of a material? Traditionally, surface modification has been achieved by utilizing specific chemical reactions, deposition and growth, and atomic manipulation using the scanning tunnelling microscope. We are currently exploring another route to the nano-structural engineering of materials, one which exploits the phenomenon of electromigration. This work is performed in collaboration with the NSF Materials Science and Enginneering Center based at the University of Maryland.

Surface electromigration describes mass transport at the surface of a solid that is driven by an electrical current. Electromigration is well-known phenomenon in bulk materials and it has been implicated as a cause of interconnect failure in integrated circuits where interfacial (grain boundary) migration is the primary failure mechanism in micron-scale metallic lines. By contrast, in nanoscale electronic devices the dominant electromigration pathway is the surface of the material.

We are developing quantum mechanical theory of the electromigration force at surfaces. Our theory can be tested directly by scanning tunneling microscopy studies of adatom migration in the presence of a surface current. This phenomenon could be exploited to enable the external manipulation of atomic and cluster diffusion at surfaces. Put simply, by controlling the electrical current flowing at the surface of a material it may be possible to change the magnitude and direction of the driving force causing electromigration.

The theory of electromigration has an important application to gas sensor technology based on metallic films. It is well known that atomic or molecular adsorption onto the surface of a conducting thin film changes its resistivity since the adsorbates act as scattering centers for carriers striking the surface. Therefore the contribution of an adsorbate to the surface resitivity of the film is directly related to the electromigration force acting upon the particle. Since this magnitude of this force is a strong function of the scattering properties of the adsorbate, the change in surface resistivity upon adsorption is chemically specific.